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Supporting Information for

Pulse-Like Partial Ruptures and High-Frequency Radiation Next to Creeping-Locked Transition during Megathrust Earthquakes

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Introduction

We present supporting information on the conditions required to produce partial ruptures in our simulations.

Text S1.

Figure S1 illustrates the change of earthquake rupture extent in our model when the nucleation size changes with respect to the width of the velocity-weakening (VW) patch. We find that if the ratio of the nucleation size and the VW patch width is smaller than ~0.08, partial ruptures are produced in our simulation. On the contrary, above this threshold, only full ruptures are produced. The value of this threshold is dependent on the frictional parameters that we have chosen in our model. The geometry of the VW patch also influences the behavior of seismic events. For instance, some full ruptures actually begin as partial ruptures but are then revitalized as they meet a neighboring border of the VW patch. Increasing the length of the VW patch would then increase the threshold, for example. Further investigations need to be done to better understand the impact of the geometry of the VW patch and its frictional parameters on the ratio h^*/W required for partial ruptures in a frictionally homogeneous VW area.

Text S2.

Figure S2 compares slip, stress and high frequency radiation from a section of event 12. The high frequency amplitude is slightly asymmetric, skewed towards the border of the VW region. Its maximum is offset from the maximum slip location. This observation is clearer while looking at event 13, which is a full rupture (Figure S3). The high frequency radiation sources are located in zones of higher stress. The zones with large slip are, however, not correlated with the location of the high-frequency sources.

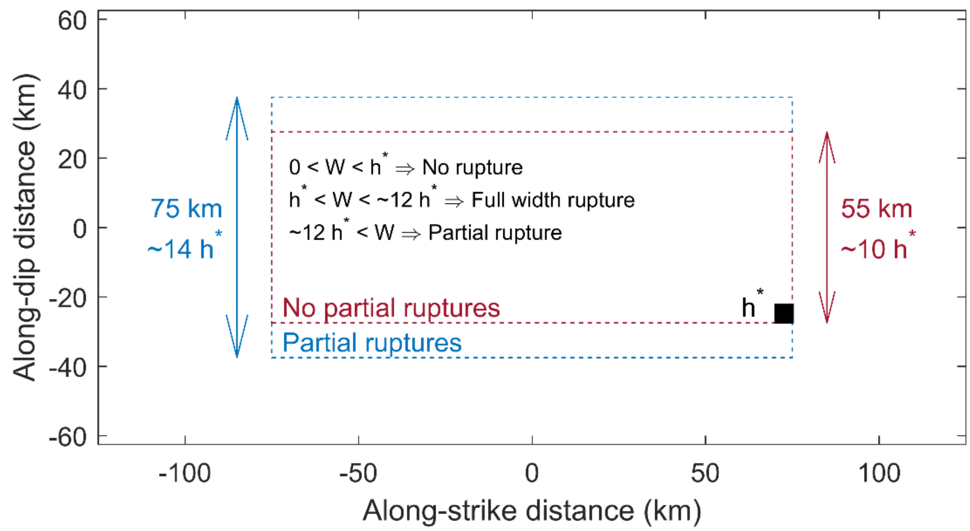

Figure S1. Illustration of how the width of the VW patch, W, and nucleation size, h*, control the occurrence of partial ruptures in our model. With the parameters considered, the nucleation size, $\mathbf{h}^*$, needs to be smaller than approximately 1/12 of the width of the VW patch ($\mathbf{h}^*/\mathbf{W} < \sim 0.08$) for the partial ruptures to occur. Otherwise, only full ruptures of the VW patch are produced. The threshold on $\mathbf{h}^*/\mathbf{W}$ may depend on the choice of frictional parameters and geometry of the VW patch.

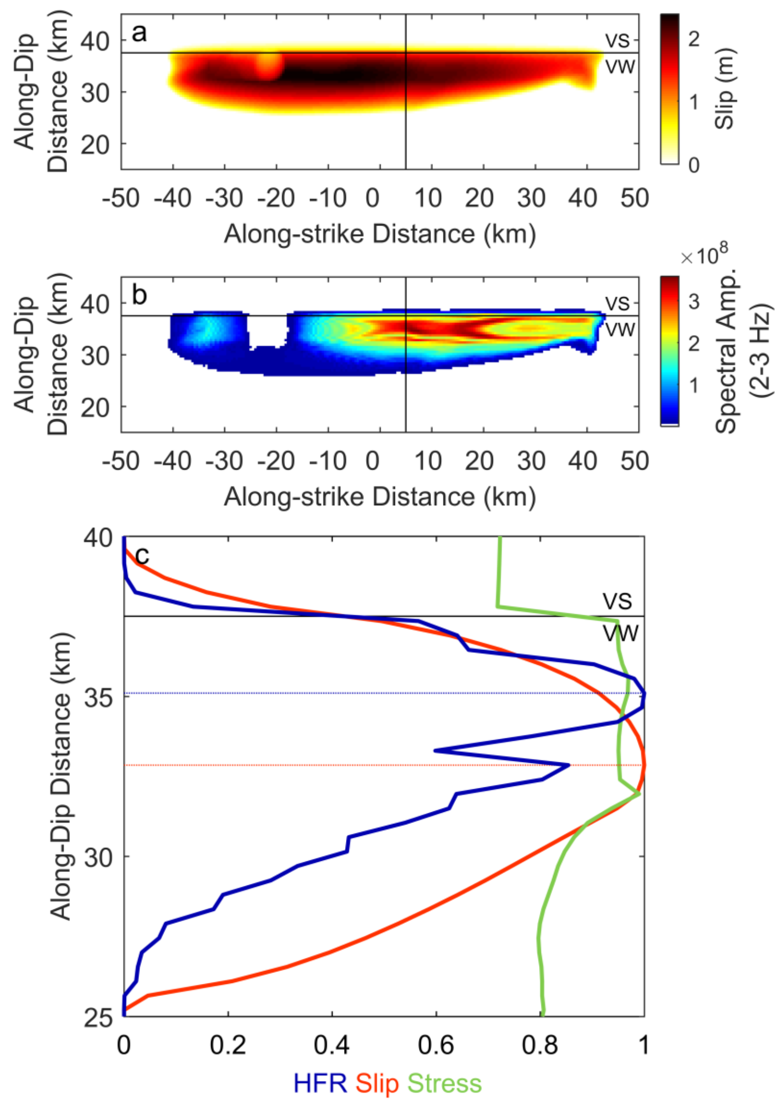

Figure S2. High-frequency radiation, slip and pre-event shear stress comparison from a vertical section. (a) Slip distribution of event 12 with the vertical section marked. (b) Map of high-frequency sources during the rupture. Color shading shows the spatial variations of the amplitude of the spectrum of the slip-time function between 2 and 3 Hz. The solid black horizontal line is the limit between the VS and VW areas. The solid vertical black line indicates the location of the section shown in (c). (c) Normalized spectral amplitude between 2-3 Hz (blue), slip (red) and pre-stress (green) along the section indicated in (a) and (b). HFR stand for High Frequency Radiation. The horizontal blue and red lines locate the maximum slip and spectral amplitude, respectively. Note that the maximum high-frequency radiation is offset with respect to the maximum slip and located closer to the VW/VS transition.

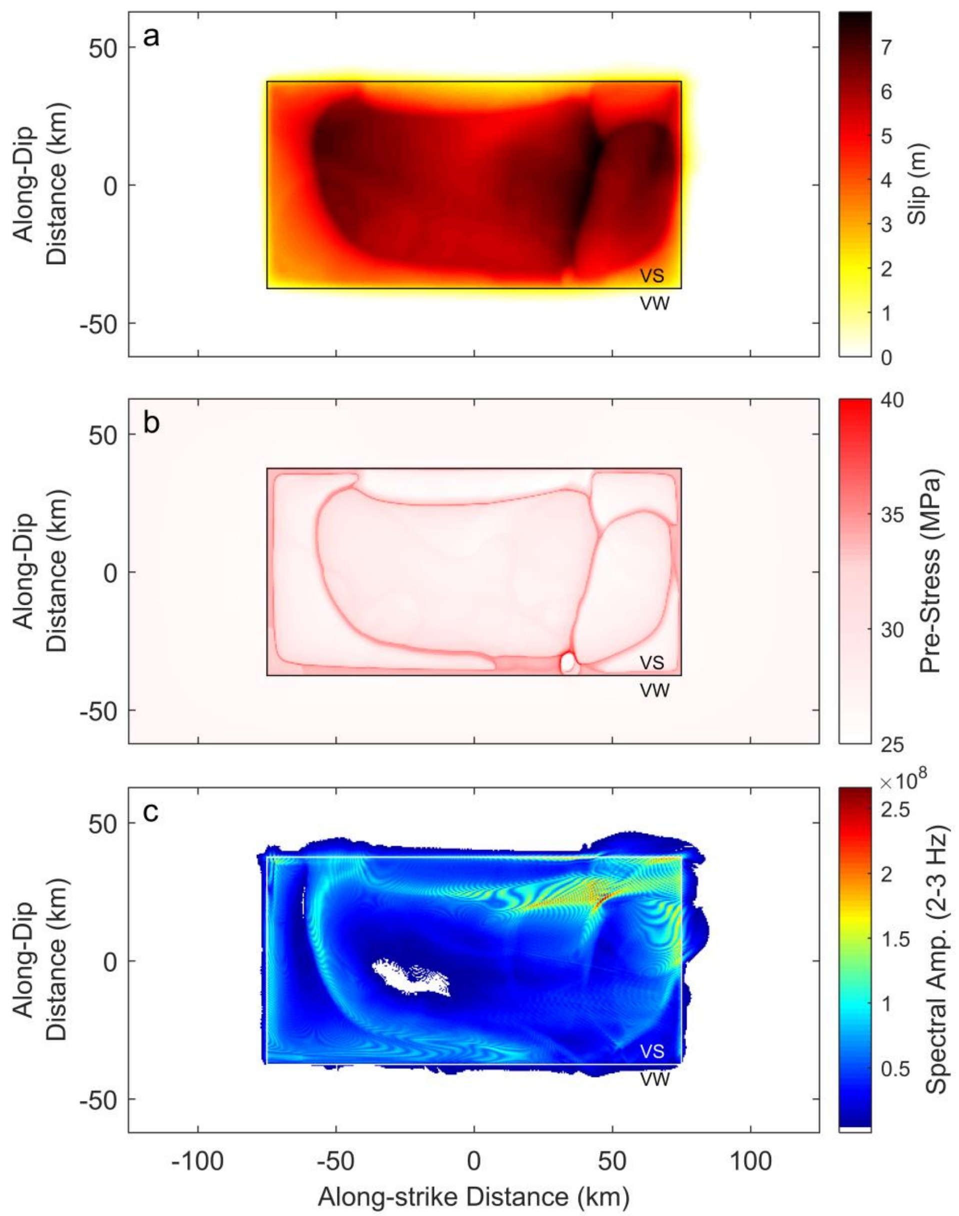

Figure S3. Cumulative slip, pre-stress and high-frequency radiation source maps of a full rupture (event13). (a) Cumulative slip of the event. (b) Shear stress at the onset of seismic event, when the slip rate exceeds 0.1 m/s somewhere on the fault. The stress has already dropped where nucleation has been occurring. The color scale is saturated to better visualize the stress distribution. The maximum and minimum shear stress on the fault are 45.1 MPa and 24.7 MPa, respectively. (d) Map of high frequency sources during the rupture. Color shading shows the amplitude of the spectrum of the slip-time-function between 2 and 3 Hz. The solid black or white rectangle is the limit between the VS and VW areas.

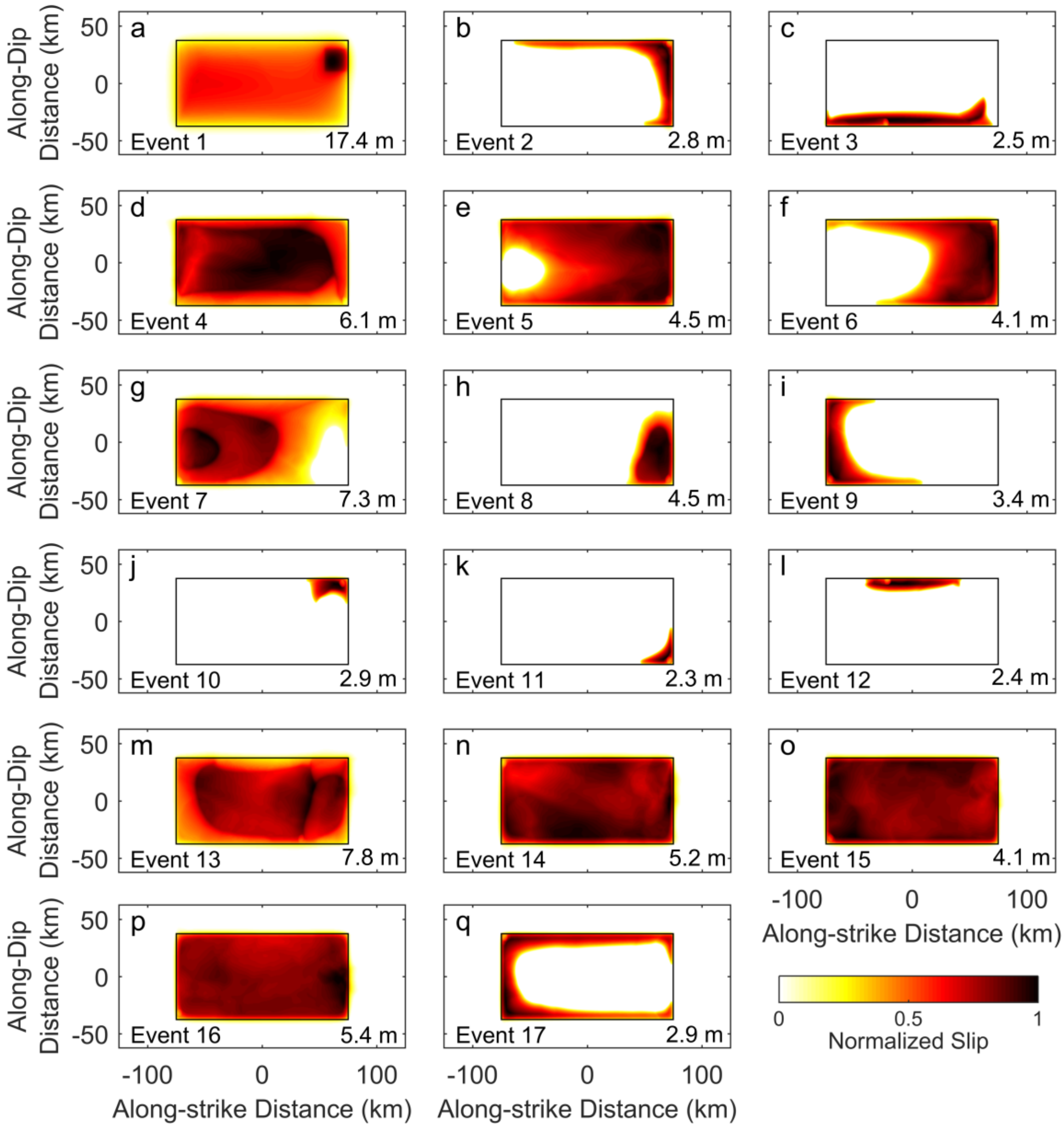

Figure S4. Normalized slip distribution of all the events of our simulation. The bottom right number indicates the maximum slip of each event.

Data Set S1.

This data set includes the cumulative slip results of the 17 events of our simulation, as well as the shear stress at rupture onset and amplitude of the moment rate function spectrum between 2-3 Hz of event 12 and 13 (as shown in figure 2, S3 and S4). These data are meshgrids of 277x555 size, representing the cells of the fault plane. The coordinates of each cell center are given by the files Coord_Fault_X.txt and Coord_Fault_Y.txt (in km). The size of each cell is equal to 450x450 m^2, a down sampled version of the fault in the simulation which cells size are equal to 150x150 m^2.

Event_1_Disp.txt to Event_17_Disp.txt are the cumulative slip results (in m) of events 1-17 (figure 2a, S3a and S4).

Event_12_PreStress.txt and Event_13_PreStress.txt correspond to the shear stress (in Pa) at rupture onset of event 12 and 13 (figure 2c and S3b).

Event_12_HFR.txt and Event_13_HFR.txt correspond to the amplitude of the moment rate function spectrum between 2-3 Hz of event 12 and 13 (figure 2d and S3c).

Event_12_Propagation.txt corresponds to the rupture front propagation of event 12 (figure 2b). The file indicates the location where slip rate exceeds 0.5 m/s, and the values indicate the timing during the rupture (in s).

Data Set S2.

This data set includes the source-time function (moment rate as a function of time) of event 12, as well as the cumulative slip, shear pre-stress, and slip rate of event 12 at the locations of points A and B from Figure 1b (as shown in figure 3). The first line of each files indicate the time from the onset of the rupture. The second line indicate either the source time function, cumulative slip, shear pre-stress, or slip rate of event 12.

Event_12_MoRate.txt corresponds to the source time function (in N.m/s) of event 12 (figure 3a).

Event_12_Slip_vs_time.txt corresponds to the cumulative slip (in m) of event 12 (figure 3b).

Event_12_Stress_vs_time.txt corresponds to the shear pre-stress (in MPa) of event 12 (figure 3c).

Event_12_Rate_vs_time.txt corresponds to the slip rate (in m/s) of event 12 (figure 3d).

Data Set S3.

This data set includes the result of maximum slip rate as a function of time during the 2000-year-long simulation, as well as the earthquake catalogue of our model (as shown in figure 1c).

EQ_catalogue.txt corresponds to the earthquake catalogue. It is organized as followed: Earthquake #, time of events onset (in seconds since the beginning of the simulation), time of events end (in seconds since the beginning of the simulation), moment magnitude.

Vmax.txt corresponds to the maximum slip rate as a function of time during the 2000-year-long simulation. The first column is the time in seconds. The second column is the logarithm of slip rate (in m/s).

Movie S4. Event 12 slip rate history. The slip rates are indicated in log scale.